R E P O R T R E S U M E S

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THE COMPARATIVE EFFECTIVENESS OF SOUND MOTION PICTURES AND PRINTED COMMUNICATIONS FOR THE MOTIVATION OF HIGH SCHOOL STUDENTS IN MATHEMATICS.

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IN AN EFFORT TO PROVIDE A BETTER UNDERSTANDING OF MOTIVATION AND TO INVESTIGATE SOME POSSIBLE MEANS FOR INCREASING THE MOTIVATION OF STUDENTS, MOTION PICTURES AND PRINTED COMMUNICATIONS WHICH ILLUSTRATED PRACTICAL APPLICATIONS OF MATHEMATICAL CONCEPTS WERE TESTED. SUBJECTS FOR THE STUDY WERE DRAWN FROM FIRST-YEAR ALGEBRA CLASSES FROM 17 HIGH SCHOOLS. THE FOLLOWING HYPOTHESES WERE TESTED--(1) SHOWING A HIGH SCHOOL STUDENT THAT A KNOWLEDGE OF MATHEMATICAL CONCEPTS IS POSITIVELY RELATED TO HIS VOCATIONAL GOALS WILL MOTIVATE HIM IN SUCH A WAY THAT HE WILL HAVE A MORE FAVORABLE ATTITUDE TOWARD THE SUBJECT, SHOW A GREATER INTEREST IN LEARNING, AND ACQUIRE A GREATER KNOWLEDGE OF MATHEMATICS, AND (2) SOUND MOTION PICTURE FILMS WHICH ILLUSTRATE PRACTICAL APPLICATIONS OF MATHEMATICS ARE MORE EFFECTIVE THAN COMPARABLE PRINTED COMMUNICATIONS FOR MOTIVATING SUBJECTS. THE AUTHOR CONCLUDES THAT HIS EXPERIMENTAL HYPOTHESES WERE SUPPORTED BY THE DATA. FURTHER RESEARCH OF THE PROBLEM IS RECOMMENDED. (JC)

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One of the major problems which most educators face is that of arousing a pupil's interest or desire to learn more about a particular subject. If the student lacks this interest or desire, he is said to have little or no "motivation."

"Motivation" has been given a great deal of attention in the literature of educational psychology. Educators have been convinced for some time that it is essential to learning. The problem of defining motivation in operational terms, however, and experimental investigation of ways in which motivation is related to a student's behavior in the classroom have been almost entirely neglected.

Educators have assessed motivation in terms of the kind and amount of a student's behavior. For example, if a student reads many books on American History, he is said to be "motivated" in that particular subject. If motivation is going to be a useful contruct, however, it is necessary to identify the antecedent conditions as well as the consequent response variables. To know that it is necessary to motivate a student is not enough. We must also know what variables act as motivating stimuli.

In an effort to provide a better understanding of motivation and to investigate some possible means for increasing the motivation of students, motion pictures and printed communications which illustrated practical applications of mathematical concepts were tested in this study.

Motivation can be defined as the conditions or states within an individual which initiate, sustain, and direct his behavior toward certain goals.[1] The importance of motivation to learning is obvious. Since learning is a type of behavior, motivation is a necessary antecedent condition of learning and the extent and efficiency of learning will presumably be a positive function of the strength of the motivational factors. It is important to realize, also, that the behavior which is initiated by an individual's motivation is directed toward his goals or needs. As Thomas has stated:

> Learning cannot be poured into him /the student/; he must actively desire it. Before he will learn, he must want to learn. And he will want to learn only those things which he thinks will satisfy his needs.[2]

One would hypothesize from this that a student can be motivated to behave in a particular way by showing him how this behavior is a possible means to the goals he is seeking to achieve. If, for example, a student is shown that his goals are positively related to a knowledge of mathematical concepts, he will presumably be motivated to learn these mathematical concepts.

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[1]Suggested by E. I. Sawin, "Motivation in Mathematics: Its Theoretical Basis, Measurement, and Relationships with Other Factors" (Doctoral Dissertation, University of Chicago, 1951).

[2]R. Murray Thomas, "The Teacher Introduces Learning Tasks," Learning and the Teacher, 1959 Yearbook of the Association for Supervision and Curriculum Development (Washington, D. C.: National Education Association, 1959), p. 72.

PURPOSE OF THE STUDY

The present experiment was designed to test the above hypothesis. In addition, motion picture films and printed booklets were compared as media for communicating the motivational materials.

Thus, the following specific hypotheses were tested:

A. Showing a high school student that a knowledge of mathematical concepts is positively related to his vocational goals will motivate him in such a way that he will:

   1. Have a more favorable attitude toward mathematics.

   2. Show a greater interest in learning about mathematical concepts.

   3. Acquire a greater knowledge of mathematics.

B. Sound motion picture films which illustrate practical applications of mathematics are more effective than comparable printed communications for motivating students.

Information was also sought on the following questions:

A. Do either the films or printed materials have an effect on whether a student will take additional courses in mathematics?

B. What is the relationship between the grades a student receives in mathematics and his liking for mathematics?

C. What is the relationship between the degree to which a student likes his mathematics teacher and his liking for mathematics?

D. What is the relationship between a student's liking for mathematics and his ability to solve mathematical problems?

E. What is the relationship between a student's expressed interest in learning more about mathematical concepts and his ability to solve mathematical problems?

F. What is the relationship between a teacher's rating of a student's motivation in mathematics and the student's ability to solve mathematical problems?

G. What is the relationship between a teacher's rating of a student's motivation in mathematics and the student's liking for mathematics?

H. What is the relationship between a teacher's rating of a student's motivation in mathematics and the student's expressed interest in learning more about mathematical concepts?

PROCEDURE

In order to test the hypotheses and answer the questions outlined above, the following procedure was employed:

A. First-year algebra classes were randomly assigned to three treatment groups.

1. The students in treatment group I were shown three motion picture films during the second semester of the 1960-61 school year. These films are described below.

2. Students in treatment group II received comparable material as those in group I except that it was presented in printed booklets rather than films. These were also presented during the second semester of the 1960-61 school year. The booklets are described below.

3. Treatment group III was used as a control and received no experimental treatment.

B. Each group was pre-tested at the beginning of the semester and post-tested at the end of the semester in which the experiment was conducted.

Sampling Procedure

First-year algebra classes from seventeen high schools within a 30-mile radius of Iowa City, Iowa were used in the experiment. High schools with enrollments of less than 75 or more than 400 were excluded from the experiment. These schools were excluded in order to obtain the greatest possible efficiency in administering the experimental treatments to a maximum number of students.

There are twenty-one high schools within a 30-mile radius of Iowa City with enrollments between 75 and 400; but three of these did not agree to participate in the experiment and one school did not offer a course in first-year algebra during the 1960-61 school year.

Some of the high schools used in the experiment had two first-year algebra classes. With one exception, both classes in each school were considered as one group and were given the same treatment. One exception was made so that the total number of groups would be eighteen. Thus there were six high schools assigned to each of the three treatments

The sample was divided into two strata. Those schools in which the class enrollment in first-year algebra was greater than 25 were placed in one stratum and those in which the enrollment was less than 25 were placed in another stratum. This was done to counterbalance any effect class size may have had on the criterion measures. Each school within each stratum was then randomly assigned to one of the three treatments. A total of 550 subjects participated in the experiment. Table 1 shows the number of subjects in each treatment group.

TABLE 1

NUMBER OF SUBJECTS IN EACH TREATMENT GROUP

	FILM	PRINT	CONTROL
MALES	93	87	81
FEMALES	102	96	91
TOTAL	195	183	172

The Experimental Films

Three sound motion picture films were produced by the author at the State University of Iowa Division of Television-Radio-Film for use in the experiment. Each of these films was approximately fifteen minutes in length. The films were desinged to illustrate practical applications of algebra in everyday life and in various kinds of occupations. (Scripts of the films may be seen in Appendix A.)

Three prints of each film were made to facilitate their distribution to the six schools in treatment group I. The teachers were told to show the films at their convenience and were encouraged to relate each film to the particular subject-matter that they were teaching at that time. The teachers showing the films were given the following instructions:

> After showing the film to your class(es) ask the students if they have any questions or comments on what they have seen. It is hoped that the films will lead to some discussion concerning the applications of algebra.

The Experimental Booklets

The ideas which were illustrated in the three experimental films were organized into written form and presented to those students in treatment group II, in a series of three, 6 to 8-page, printed booklets. The booklets contained little visual material. However, a few sketches, to illustrate the graphing of equations and the concept of similar triangles, were used in two of the three booklets. The booklets were comparable to the films to the extent that they presented the same content but, in order to illustrate the same ideas,

additional wording that was not included in the sound-tracks of the films was sometimes needed in the booklets. (The content of these booklets is presented in Appendix B.)

Enough booklets were printed so that there was a copy for each student in the classes assigned to treatment group II. The teachers were told to use the booklets at a time which was convenient for them and were encouraged to relate them to the particular subject-matter that they were teaching at that time.

Teachers of the classes in treatment group II were given the following instructions:

> In using these materials, give your class(es) a few minutes to read the booklets (five or ten minutes should be sufficient); then ask the students if they have any questions or comments on what they have read. It is hoped that the booklets will lead to some discussion concerning the applications of algebra.

It is important to note that the students in treatment group II were given time in class to read each booklet just as the students in treatment group I were given time to view each film.

Collection of Data

The following data were collected from all groups at the beginning and at the end of the semester in which the experiment was conducted:

1. Scores on a Motivation Inventory which was constructed as a part of this study. This instrument is described in further detail below.

2. Scores on the Lankton First-Year Algebra Test.[1] Different forms of this test (Am and Bm) were used at the beginning and end of the semester. Half of the schools in each treatment group received from Am at the beginning of the semester and form Bm at the end of the semester. The other half received form Bm at the beginning and form Am at the end.

3. Teachers' ratings of students based on the degree to which they perceived each of their students to be motivated. The rating form consisted of two parts. The first part asked the teacher to rate each student's general behavior in algebra class. The second part of the rating form asked the teacher to rate each student's work and participation in class. (This rating form is shown in Appendix C.)

The Motivation Inventory was administered to all students by the experimenter or one of his assistants. It was administered during a regular class period. Each teacher was asked to leave the classroom before the test was administered and asked not to return until all students had finished. In administering the pre-test, the following instructions were read to the students:

> This questionnaire is being given to students from several high schools in Iowa in an attempt to gather information concerning their attitudes toward what they study in school. Since the only way to learn of students' attitudes is to find out their opinions toward certain issues, we hope that your answers to the questions presented here will be honest and reflect your true feelings.
>
> Under no circumstances will your responses be used by your teachers or by your school to appraise individual students. Your opinions will be used for research purposes only and will be kept confidential. In other words, none of your teachers will be allowed to read your answers.

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[1] Robert Lankton, Lankton First-Year Algebra Test (Yonkers-on-Hudson: World Book Company, 1951).

In administering the post-test the following instructions were read to the students:

> You probably remember answering this questionnaire at the beginning of this semester. Now that you have finished the school year, we would like to know if you have changed any of your opinions or attitudes toward what you have studied this semester. Under no circumstances will your responses be used by your teachers or by your school to appraise individual students. Your opinions will be used for research purposes only and will be kept confidential. In other words, your teachers will not be allowed to read your answers.

The students were given no indication that this test was to be used to evaluate only their attitude toward algebra. Questions on the Motivation Inventory asked students their opinions toward other subjects they were studying as well as their opinions toward algebra.

The Lankton First-Year Algebra Test was given to each student approximately one week after the Motivation Inventory and was administered by the teacher of each class. The teachers were given the following instructions in addition to the standard procedure for administering the test:

> Tell your students they are being given the test in order to evaluate the progress they have made and to compare their scores with average scores of other high schools. Encourage them to do their best without letting them know that the results are being used in the experiment. Also, it is important that you do not indicate that this test is in any way related to the questionnaire they have answered previously.

Each teacher was also told, "It is important that exactly 40 minutes be allowed for the test in order to get an accurate interpretation of the results."

THE MOTIVATION INVENTORY

In order to evaluate a student's attitude toward mathematics and the student's interest in learning more about mathematical concepts, a Motivation Inventory was constructed as a part of this study. The instrument is divided into four sections.

The first section of the Motivation Inventory asks the student to list the subjects he is taking in school and to indicate whether he likes, dislikes, or is indifferent toward each subject. This is followed by a series of questions which asks the student to indicate:

1. Which subject he likes most and which subject he dislikes most.
2. Which subject he thinks is most interesting and which subject he thinks is least interesting.
3. Which subject he thinks will be most valuable and which subject he thinks will be least valuable to him when he finishes high school.
4. Which subject his favorite teacher teaches and which subject the teacher he likes least teaches.
5. In which subject he makes the best grades and in which subject he makes the poorest grades.

In scoring this section of the Motivation Inventory, a score of zero is given for each unfavorable response toward algebra (i.e., if the student expresses a "dislike" for algebra, mentions algebra as being "disliked most," "least interesting," "least valuable," etc.). A score of one is given for those responses in which no mention of algebra is made or if the student expresses an indifference toward algebra. A score of two is given for each favorable response (i.e., if the student expresses a "like" for algebra, mentions algebra as being

"liked most," "most interesting," "most valuable," etc.).

The total score for this section of the Motivation Inventory is derived from questions which indicate the following:

1. A like, dislike, or indifference toward algebra.
2. Algebra mentioned as being liked most or disliked most.
3. Algebra mentioned as the most interesting or least interesting subject.
4. Algebra mentioned as the most valuable or least valuable subject.

The sum of scores from each of these is hereafter referred to as the Attitude toward Algebra score.

The second section of the Motivation Inventory is designed to measure the connotative meaning algebra has for a student. It employs a form of the semantic differential.[1] In this section of the test, the student is asked to rate Algebra, English, and Science using the following scales:

senseless__:__:__:__:__:__:__sensible*

painful__:__:__:__:__:__:__pleasurable*

*important__:__:__:__:__:__:__unimportant

*strong__:__:__:__:__:__:__weak

*excitable__:__:__:__:__:__:__calm

*large__:__:__:__:__:__:__small

*alive__:__:__:__:__:__:__dead

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[1] Charles E. Osgood, George J. Suci, and Percy H. Tannenbaum, The Measurement of Meaning (Urbana: University of Illinois Press, 1957).

unnecessary __:__:__:__:__:__:__necessary*

heavy __:__:__:__:__:__:__light*

*practical __:__:__:__:__:__:__impractical

dull __:__:__:__:__:__:__stimulating*

bad __:__:__:__:__:__:__good*

*Signifies which end of the scale was scored as high.

The ratings of English and Science were not used in this study. They were included in the Motivation Inventory to reduce the probability of the student realizing that only his reactions toward algebra were being sought.

For scoring this section of the Motivation Inventory a digit has been assigned to each interval on each scale. These digits range from zero (at the negative end of the scale) to six (at the positive end of the scale). The score for each scale is the digit corresponding to the interval which is checked. In their factor analyses of the semantic differential, Osgood, Suci, and Tannenbaum[1] found three independent dimensions of meaning. Thus, there are three scores from this section of the Motivation Inventory. The sum of the "excitable-calm" and "alive-dead" scales is termed the Activity dimension score; the sum of the "strong-weak," "large-small," and "heavy-light" scales is termed the Potency dimension score; and the sum of the other scales is termed the Evaluative dimension score. Each of these dimension scores is treated separately in the analyses of the data.

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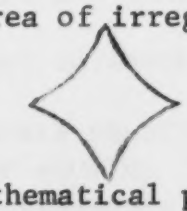
[1] Ibid.

The third section of the Motivation Inventory is used to determine the degree of interest a student has in learning more about mathematics. It employs a technique which is similar to that used by Sawin.[1] The student is asked to indicate whether he is "definitely interested," "a little interested," "not very interested," or "definitely not interested" in finding out more about each of the following topics:

1. Why our number system is based on 10 instead of some other number.
2. The meaning of zero--whether it is or is not a number.
3. How subtraction can be explained on the basis of counting.
4. Why multiplication is a shortcut for adding.
5. Why it is necessary to find a common denominator in adding fractions, but not in multiplying them.
6. Why we invert the divisor when we divide by a fraction.
7. How many ways there are to find the square root of a number, and how they work.
8. How to find the area of irregular shapes, such as the one shown below.



9. The meaning of mathematical probability.
10. How the theory of mathematical probability is used in scientific research.
11. The kinds of things that are studied in advanced algebra.
12. How we arrive at new formulas, such as those used for solving motion problems.

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[1] E. I. Sawin, op. cit.

13. What calculus is and how it works.

14. How to operate a slide rule.

15. What logic is and how it is related to mathematics.

16. Einstein's theories of relativity and gravitation.

17. How π (pi) is determined.

18. How algebra is used in research in the social sciences such as speech, sociology, psychology, and history.

19. How algebra is used in engineering, architecture, surveying, physics, and chemistry.

20. How algebra is used in business and banking.

21. How algebra is used by doctors and dentists--why mathematics is ususally required for medical training.

22. How the diameter of the earth was determined.

23. How eclipses of the sun and moon can be predicted over long periods of time.

24. How the pythagorean theorem was discovered.

25. How mathematical progress has influenced civilization.

26. How algebra is used in launching earth satellites.

27. How magic squares are constructed. (The following is an example of a magic square. Each of the rows, each of the columns, and both diagonals add up to 30.)

16	2	12
6	10	14
8	18	4

28. How mathematics and algebra are used in games.

29. How to make various geometrical designs.

Section IV of the Motivation Inventory consists of two questions. (This section was used in the post-test only.) The questions are as follows:

1. Do you plan to take any other courses in mathematics before you finish high school? (check one)

   _____definitely yes _____probably not

   _____probably _____definitely not

2. If you do plan to take additional courses in mathematics, which ones will you take?

   _____ _____

   _____ _____

TREATMENT OF THE DATA

To test for the significance of differences among the three treatment groups, analyses of covariance with the individual as the unit of measurement were used.[1] Separate analyses of covariance were made for each of the following criterion measures:

1. The Attitude toward Algebra scores.
2. The Activity dimension scores.
3. The Potency dimension scores.
4. The Evaluative dimension scores.
5. The Interest in Mathematics scores.
6. The Lankton First-Year Algebra Test scores.

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[1] E. F. Lindquist, Design and Analysis of Experiments in Psychology and Education (Boston: Houghton Mifflin Company, 1956), pp. 317-336.

Tests of homogeneity of regression were also made on these data. As Lindquist points out, of the assumptions underlying the test of significance of treatment effects, "perhaps the most critical in practice is the assumption that the regression of Y /criterion variable/ on X /control variable/ is the same for all treatment populations."[1]

In each case the post-examination was used as the criterion variable and the corresponding pre-examination was the control variable.

Chi Square tests were used to determine whether the treatment groups differed significantly in the proportion of students who indicated they would take additional courses in mathematics.

Pierson product-moment coefficients of correlation were used to assess the relationships among the various criterion measures and to assess the relationships between these measures and teachers' ratings.

Contingency coefficients of correlation[2] were used to assess the relationships among the following factors: (1) the student's like or dislike for algebra, (2) the student's ranking of algebra as being his most or least interesting subject, (3) the student's ranking of algebra as being his most or least valuable subject, (4) the student's ranking of his algebra teacher as being liked most or liked least, and (5) the student's ranking of his grades in algebra compared to his grades in the other subjects he is taking.

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[1] Ibid., p 330.

[2] Merle W. Tate, Statistics in Education (New York: The Macmillan Company, 1955), pp. 261-264.

In all analyses or tests of significance, the 5 per cent level of confidence was pre-set as the level at which to reject the hypothesis of no difference.

RESULTS

Table 2 shows the F-ratios obtained from the analyses of covariance using scores from the Motivation Inventory and the Lankton First-Year Algebra Test. None of the tests of homogeneity of regression yielded a significant F-ratio. This indicates that the assumption of equal regression of the post-measure on the pre-measure in all treatments could be retained for all criterion measures. The analysis of

Table 2

F-RATIOS OBTAINED FROM TESTS OF HOMOGENEITY OF REGRESSION AND ANALYSES OF COVARIANCE

Criterion Measure	F-ratio for test of homogeneity of regression	F-ratio for Analysis of Covariance
Attitude toward Algebra	2.251	4.433*
Activity dimension	1.581	6.437*
Potency dimension	$\angle 1$	1.507
Evaluative dimension	$\angle 1$	5.869*
Interest in Mathematics	1.933	2.110
Lankton First-Year Algebra Test	1.234	16.966*

*F = 2.99 is significant at the .05 level of confidence

covariance F-ratios for the Potency dimension scores and the Interest in Mathematics scores were not significant. However, significant differences among the three treatment groups were found on the other four criterion measures. In order to locate these differences more precisely, t-tests were made to determine the significance of the difference between each pair of adjusted means for each of these four criteria.

Table 3 shows the differences between adjusted means for each pair of treatment groups using the Attitude toward Algebra score as the criterion variable. As can be seen from the table, the adjusted mean score for the film group is significantly higher than the adjusted mean scores for the print group and control group. However, the difference between the print group and control group is not significant.

Table 3

TABLE OF SIGNIFICANT DIFFERENCES BETWEEN ADJUSTED MEANS OF THE ATTITUDE TOWARD ALGEBRA SCORES

Treatment	Print	Control
Film	.313*	.486*
Print		.173

*Significant at the .05 level of confidence.

M_F = 4.822

M_P = 4.509

M_C = 4.336

Table 4 shows the differences between adjusted means for each pair of treatment groups using the Activity dimension score as the criterion variable. The mean score for the film group is significantly higher than the mean scores for the print and control groups. No significant difference was found between the print group and the control group.

Table 4

TABLE OF SIGNIFICANT DIFFERENCES BETWEEN ADJUSTED MEANS OF THE ACTIVITY DIMENSION SCORES

Treatment	Print	Control
Film	.760*	.939*
Print		.179

*Significant at the .05 level of confidence.

$M_F = 6.934$

$M_P = 6.174$

$M_C = 5.995$

Table 5 shows the differences between adjusted means for each pair of treatment groups using the Evaluative dimension score as the criterion variable. As is shown in the table, the mean score for the control group is significantly lower than the mean scores for the experimental treatment groups. The difference between the film group and the print group is not significant.

Table 6 shows the differences between individual adjusted means of each pair of treatment groups using the Laukton First-Year Algebra Test score as the criterion variable. Again, the mean score for the

Table 5

TABLE OF SIGNIFICANT DIFFERENCES BETWEEN ADJUSTED MEANS OF THE EVALUATIVE DIMENSION SCORES

Treatment	Print	Control
Film	.850	2.141*
Print		1.291*

*Significant at the .05 level of confidence.

M_F = 31.514

M_P = 30.664

M_C = 29.373

Table 6

TABLE OF SIGNIFICANT DIFFERENCES BETWEEN ADJUSTED MEANS OF THE LANKTON FIRST-YEAR ALGEBRA TEST SCORES

Treatment	Print	Control
Film	4.641*	4.385*
Print		.256

*Significant at the .05 level of confidence.

M_F = 38.783

M_P = 34.142

M_C = 34.398

film group is significantly higher than the mean scores for the print and control groups. No significant difference was found between the print group and the control group.

Table 7 presents a summary of the significant differences between pairs of groups for all of the criterion measures for which significant differences were found among the three treatment groups. As the table

Table 7

SUMMARY OF SIGNIFICANT DIFFERENCES BETWEEN PAIRS OF TREATMENTS ON ALL CRITERION MEASURES WHICH YIELDED A SIGNIFICANT F-RATIO

Criterion	Differences Between Treatments: Film and Control	Film and Print	Print and Control
Attitude toward Algebra	Significant	Significant	Non-Significant
Activity Dimension	Significant	Significant	Non-Significant
Evaluative Dimension	Significant	Non-Significant	Significant
Lankton First-Year Algebra Test	Significant	Significant	Non-Significant

shows, the differences between the adjusted mean scores for the film group and the control group were significant on all of the criterion measures; the differences between the film group and the print group were significant on three of the criterion measures; and the difference between the print group and the control group was significant on one of

the criterion measures.

In order to determine whether these results held true for both males and females, additional analyses of covariance were made for each sex. Table 8 shows the obtained F-ratios using only the male subjects.

Table 8

F-RATIOS OBTAINED FROM TESTS OF HOMOGENEITY OF REGRESSION AND ANALYSES OF COVARIANCE USING MALE SUBJECTS ONLY

Criterion Measure	F-ratio for Test of Homogeneity of Regression	F-ratio for Analysis of Covariance
Attitude toward Algebra	1.195	5.644*
Activity Dimension	2.822	7.070*
Potency Dimension	$\angle 1$	2.836
Evaluative Dimension	$\angle 1$	5.164*
Interest in Mathematics	1.791	1.557
Lankton First-Year Algebra Test	1.312	8.522*

*Significant at the .05 level of confidence.

When using only the male subjects, significant F-ratios were obtained on the same criterion measures which yielded significant F-ratios when the analyses were made using both males and females.

Tables 9, 10, 11, and 12 show the differences between pairs of adjusted means for each criterion measure for which a significant F-ratio was found.

Table 9

TABLE OF SIGNIFICANT DIFFERENCES BETWEEN ADJUSTED MEANS OF THE ATTITUDE TOWARD ALGEBRA SCORES USING MALE SUBJECTS ONLY

Treatment	Print	Control
Film	.517*	.795*
Print		.278

*Significant at the .05 level of confidence.

M_F = 5.182

M_P = 4.665

M_C = 4.387

Table 10

TABLE OF SIGNIFICANT DIFFERENCES BETWEEN ADJUSTED MEANS OF THE ACTIVITY DIMENSION SCORES USING MALE SUBJECTS ONLY

Treatment	Print	Control
Film	1.254*	1.561*
Print		.307

*Significant at the .05 level of confidence.

M_F = 6.902

M_P = 5.648

M_C = 5.341

Table 11

TABLE OF SIGNIFICANT DIFFERENCES BETWEEN ADJUSTED MEANS OF THE EVALUATIVE DIMENSION SCORES USING MALE SUBJECTS ONLY

Treatments	Print	Control
Film	1.401	2.945*
Print		1.544

*Significant at the .05 level of confidence.

M_F = 32.255

M_P = 30.854

M_C = 29.310

Table 12

TABLE OF SIGNIFICANT DIFFERENCES BETWEEN ADJUSTED MEANS OF THE LANKTON FIRST-YEAR ALGEBRA TEST SCORES USING MALE SUBJECTS ONLY

Treatments	Print	Control
Film	2.912*	3.357*
Print		.445

*Significant at the .05 level of confidence.

M_F = 36.676

M_P = 33.764

M_C = 33.319

The adjusted mean score of the film group was significantly higher than the adjusted mean scores of the print group and the control group for the Attitude toward Algebra score, Activity dimension score, and the Lankton First-Year Algebra Test score. When using the Evaluative dimension score as the criterion measure, the adjusted mean score of the film group was significantly higher than that of the control group but there was no significant difference between the film group and the print group. None of the differences between the print group and the control group was significant. Table 13 presents a summary of the significant

Table 13

SUMMARY OF SIGNIFICANT DIFFERENCES BETWEEN PAIRS OF TREATMENTS ON ALL CRITERION MEASURES WHICH YIELDED A SIGNIFICANT F-RATIO FOR MALE SUBJECTS ONLY

Criterion Measure	Differences Between Treatments: Film and Control	Film and Print	Print and Control
Attitude toward Algebra	Significant	Significant	Non-Significant
Activity Dimension	Significant	Significant	Non-Significant
Evaluative Dimension	Significant	Non-Significant	Non-Significant
Lankton First-Year Algebra Test	Significant	Significant	Non-Significant

differences between pairs of treatments using male subjects only.

Table 14 shows the F-ratios for tests of homogeneity of regression and analyses of covariance when only the scores of the female subjects were used. As this table shows, the Lankton First-Year Algebra Test was was the only criterion measure for which the analyses of variance yielded a significant F-ratio. To locate the significant differences among treatments more precisely, t-tests were made using the Lankton First-Year Algebra Test data.

Table 14

F-RATIOS OBTAINED FROM TESTS OF HOMOGENEITY OF REGRESSION AND ANLAYSES OF COVARIANCE USING FEMALE SUBJECTS ONLY

Criterion Measure	F-ratio for test of homogeneity of regression	F-ratio for Analysis of Covariance
Attitude toward Algebra	4.739*	< 1
Activity Dimension	< 1	< 1
Potency Dimension	< 1	< 1
Evaluative Dimension	< 1	1.768
Interest in Mathematics	< 1	< 1
Lankton First-Year Algebra Test	1.569	8.798*

*Significant at the .05 level of confidence.

Table 15 shows the differences between adjusted means for each pair of treatment groups using female subjects only. The adjusted mean for the film group is significantly higher than that of the print group or the control group. The difference between the print group and control group is not significant.

Table 15

TABLE OF SIGNIFICANT DIFFERENCES BETWEEN ADJUSTED MEANS OF THE LANKTON FIRST-YEAR ALGEBRA TEST SCORES USING FEMALE SUBJECTS ONLY

Treatments	Print	Control
Film	2.147*	2.709*
Print		.562

*Significant at the .05 level of confidence.

$M_F = 36.079$

$M_P = 33.932$

$M_C = 33.370$

The test for homogeneity of regression for the Attitude toward Algebra scores was also significant when only the scores of the female subjects were used. As Lindquist points out:

> to say that the regression of Y on X is heterogeneous (but linear) is to say that there is a "treatments effect" but that the relative effectiveness of the treatments differs for different values of X /the control variable/. There may be some value of X for which the treatments are equally effective. If so, for higher values of X a certain treatment may be

> superior to a certain other treatment, but below this value the reverse would be true.[1]

In order to examine this more carefully, the Attitude toward Algebra scores for female subjects were broken down by levels. Table 16 shows the mean scores for each treatment group at four different levels. As the table shows, among female subjects who scored high on the pre-test, those in the film group scored higher on the post test than those in the print or control groups; and those in the print group scored higher than those in the control group.

Table 16

MEAN SCORES FOR DIFFERENT LEVELS OF THE ATTITUDE TOWARD ALGEBRA MEASURE USING FEMALE SUBJECTS ONLY

Level (determined by pre-test score)	FILM		PRINT		CONTROL	
	pre-test	post-test	pre-test	post-test	pre-test	post-test
0-2	1.000	2.063	1.308	2.269	1.263	2.053
3-4	3.778	3.889	3.625	3.938	3.414	3.690
5-6	5.623	5.566	5.561	5.415	5.389	4.861
7-8	7.133	7.200	7.154	6.231	7.143	5.857

In order to determine whether a significantly greater proportion of students in one treatment group indicated a probability of taking additional courses in mathematics, Chi Square tests were made using the data from Section IV of the Motivation Inventory.

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[1] Lindquist, op. cit., p. 331.

Table 17 shows the observed and expected frequencies of responses for each treatment group to the question, "Do you plan to take additional courses in mathematics before you finish high school?" The Chi Square of 18.249 is significant. As the table shows, a greater than expected frequency of students in the control group and a less than expected frequency of students in the film group indicated they would "probably" take additional courses in mathematics. It can be noted, however, that this relationship is reversed in the frequencies of students indicating they would "definitely" take additional courses in mathematics. The results of this Chi Square test was biased by an uncontrolled factor which is discussed below.

Table 17

OBSERVED AND EXPECTED FREQUENCIES OF RESPONSES TO THE QUESTION, "DO YOU PLAN TO TAKE ADDITIONAL COURSES IN MATHEMATICS BEFORE YOU FINISH HIGH SCHOOL?"

Response	Frequency	Film	Print	Control
Definitely Yes	O	119	103	95
	E	(112.391)	(105.474)	(99.135)
Probably	O	31	43	56
	E	(46.091)	(43.254)	(40.655)
Probably Not	O	33	24	15
	E	(25.527)	(23.957)	(22.516)
Definitely Not	O	12	13	6
	E	(10.991)	(10.315)	(9.694)

Chi Square = 18.249 (Significant at the .05 level of confidence)

Chi Square tests were also used to test for significant differences in the number of students from each treatment group who indicated they would take a particular course in mathematics. Table 18 shows the observed and expected frequencies and the obtained Chi Squares.

Table 18

OBSERVED AND EXPECTED FREQUENCIES OF RESPONSES TO THE QUESTION, "IF YOU DO PLAN TO TAKE ADDITIONAL COURSES IN MATHEMATICS, WHICH ONES WILL YOU TAKE?"

Response	Frequency	Film	Print	Control	Chi Square
Advanced Algebra	O	119	86	68	17.649*
	E	(96.791)	(90.835)	(85.374)	
Geometry	O	116	111	92	2.144
	E	(113.100)	(106.140)	(99.760)	
Trigonometry	O	46	27	37	4.964
	E	(39.000)	(36.600)	(34.400)	
Others	O	20	28	21	2.215
	E	(24.464)	(22.958)	(21.578)	

*Significant at the .05 level of confidence.

Only one of the Chi Square tests is significant at the .05 level of confidence. Inspection of the data in Table 18 indicates that the film treatment may have had some effect on students indicating they would take a course in advanced algebra. Although the Chi Square tests are not significant, the trend is the same for geometry and trignometry as it is for advanced algebra.

In order to evaluate the relationships among the various criterion measures used in the study, and to evaluate the relationships between

these measures and teachers' ratings of the student's motivation, Pierson product-moment coefficients of correlation were used. These correlations are shown in Table 19. In general, the highest correlations were found among the various measures from the Motivation Inventory. However, these measures did not correlate highly with the Lankton First-Year Algebra Test nor the teacher ratings. It is interesting to note that the teacher ratings correlated highest with the Lankton First-Year Algebra Test. This may indicate that teachers give much consideration to a student's ability when assessing his "motivation." The highest correlation is found between the rating of the student's general behavior in class and the rating of the student's work and participation in algebra class (r = .932).

Coefficients of correlation were also used to evaluate the relationships among the questions from the Attitude toward Algebra measure and between these questions and a student's like or dislike for his algebra teacher. In addition correlations were made to show the relationships between these measures and the student's ranking of his grades in algebra with respect to grades from other classes. The data for these correlations are from Section I of the Motivation Inventory. Since these are not continuous data, contingency coefficients of correlation were used.[1] These coefficients are shown in Table 20. It is interesting to note the high relationship which appears between a

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[1] Tate, loc. cit.

Table 19

PIERSON PRODUCT-MOMENT COEFFICIENTS OF CORRELATION AMONG CRITERION MEASURES AND BETWEEN THESE MEASURES AND TEACHERS' RATINGS

Variable	2	3	4	5	6	7	8
1. Attitude toward Algebra	.492	.484	.638	.343	.251	.271	.198
2. Activity dimension		.486	.540	.371	.162	.227	.229
3. Potency dimension			.598	.395	.195	.140	.161
4. Evaluative dimension				.464	.246	.240	.259
5. Interest in Mathematics					.188	.200	.218
6. Teacher rating of General Behavior in Algebra Class						.288	.336
7. Teacher rating of work and participation in algebra class							.932
8. Lankton First-Year Algebra Test							

r = .084 is significant at the .05 level with 550 subjects.

Table 20

CONTINGENCY COEFFICIENTS OF CORRELATION BETWEEN QUESTIONS FROM SECTION I OF THE MOTIVATION INVENTORY

Question	2	3	4	5	6
1. Like, dislike or indifferent toward algebra	.566	.456	.249	.449	.436
2. What subject do you like (dislike) most?		.550	.283	.416	.555
3. What subject do you think is most (least) interesting?	.181	.311	.372		
4. What subject do you think will be most (least) valuable to you when you finish high school?			.096	.227	
5. What subject does your favorite teacher (teacher you like least) teach?				.276	
6. In what subject do you make the best (poorest) grades?					

r = .017 is significant at the .05 level with 550 subjects.

student's like or dislike for algebra and his like or dislike for his algebra teacher. A student's like or dislike for algebra is also highly related to the grades he receives in algebra.

Another interesting fact which can be seen in Table 20 is the consistently low correlations of the various questions with the question,"What subject do you think will be most (least) valuable to you when you finish high school?" This is of particular interest when compared to the correlations in Table 19. Here the correlations of the criterion measures with the Evaluative dimension are consistently high. One would expect these two factors to be related. The scales used to obtain the Evaluative dimension score (such as: necessary-unnecessary, important-unimportant, practical-impractical) are words which would seem to describe the "value" of algebra. However, a student's Evaluative dimension score appears to be independent of his response to the question, "What subject do you think will be most (least) valuable to you when you finish high school?"

DISCUSSION OF RESULTS

The differences found among the three treatment groups clearly favor the film treatment. The film treatment group was shown to be superior to the control group on four of the six criterion measures. In addition, the film treatment was shown to be superior to the print treatment on three of these measures. The print treatment group was superior to the control group on only one of the criterion measures.

From further analyses of the data it appears that the superiority of the film treatment has some relationship to the sex of the subjects.

When only the male subjects were used in the analyses, the film group was superior to the control group on four of the six criterion measures and superior to the print group on three of the criterion measures. No significant differences appeared between the print group and the control group. When only female subjects were used, significant differences were found for the Lankton First-Year Algebra Test only. In this case the film group was superior to the other groups and there was no significant difference between the print and control groups. The data from the Attitude toward Algebra scores indicated that the film treatment may be superior to the other treatments for female subjects who scored higher initially on this particular measure.

The differences among the three treatments were not significant when the Interest in Mathematics measure was used as the criterion variable. However, as can be seen in Table 21, the differences are in the predicted direction. It is interesting to note that the "gain score"

Table 21

MEAN SCORES ON THE INTEREST IN MATHEMATICS MEASURE

Treatment	Pre-Test Mean	Post-Test Mean	Gain
Film	60.231	57.892	-2.339
Print	59.055	54.940	-4.115
Control	60.581	56.477	-4.104

for each treatment group is negative. By inspecting the pre-test and post-test means of the other measures from the Motivation Inventory one can see that the film did not bring about an increase in the students' motivation. Rather, it would appear that the function of the films was to sustain the initial level of motivation. Table 22 shows the gain scores of each treatment for all of the measures used in the study.

Table 22

GAIN FROM PRE-TEST MEAN TO POST-TEST MEAN
ON EACH CRITERION MEASURE

Criterion Measure	Film	Print	Control
Attitude toward Algebra	.128	-.116	-.044
Activity Dimension	.200	-.055	-.355
Potency Dimension	.092	.071	.122
Evaluative Dimension	-.503	-.667	-2.232
Interest in Mathematics	-2.339	-4.115	-4.104
Lankton First-Year Algebra Test	6.584	4.445	4.078

The Chi Square tests using the data from Section IV of the Motivation Inventory showed little evidence of significant differences among treatments in the proportion of students indicating they would take additional courses in mathematics. It was learned after completion of the study that most of the schools used in the experiment require one

mathematics course in addition to first-year algebra. This requirement is usally satisfied by a course in geometry or a general mathematics course. Therefore, the results of the Chi Square tests are not as meaningful as they would be if this requirement did not exist.

It is interesting to note, however, that a significantly greater proportion of students in the film group indicated they would take advanced algebra as compared with the proportion of students indicating this in the other treatment groups. It is possible that this result is due to the fact that the films used in the experiment dealt more specifically with applications of algebra than other mathematics courses.

CONCLUSIONS

Within the limitations of the experiment reported, the general hypotheses can be retained. It was shown that films which illustrate practical applications of algebra are effective in motivating high school students in mathematics.

In generalizing from the results of this study one must keep in mind that the booklets used in the print treatment contained very little visual material. It is possible that booklets containing many pictures would be as effective in motivating students in mathematics as motion picture films. Further investigation of this question is needed.

It is also important to keep in mind the potential role of the teacher in motivating students. By illustrating practical applications of mathematics in his teaching, the teacher can provide a stimulus for learning. The use of experiments in the classroom, field trips, and simply encouraging students to look for applications of the material

they are studying provide sources for motivational stimuli.

This study dealt with the problem of motivation in first-year high school algebra. The problem of motivation on other subject-matter areas needs investigation. It is possible that the methods employed in this study are applicable only in the field of mathematics. It is also possible that the methods of motivating a student by showing how a particular subject is related to his vocational goals is not effective for persons of different age groups. Answers to these and other questions are necessary if we are to make maximum use of the new media for motivating students.

APPENDIX A

FILM SCRIPTS

ALGEBRA AND ITS USES

Titles	(Title Music)
Fade out	
Fade in	
Rocket being launched	This is the launching of the Jupiter-C rocket which put the United States' first mad-made satellite into orbit around the earth. The purpose of this satellite, which was later named Explorer I, was to gather information concerning the many mysteries of outer space. Many of the problems which confront space scientists are solved by simple algebra. Of course, a knowledge of algebra alone is not enough to put a satellite into orbit. Space scientists need to use mathematics far more advanced than first-year algebra. But algebra is the basis or foundation for these mathematics just as it is the foundation for other areas of study.
Men working on space equipment.	
Girl conducting experiment in chemistry.	The study of chemistry, requires a knowledge of algebra in order to understand the relationships between elements.
Boy working on electronic equipment.	The study of physics requires a knowledge of algebra in order to understand the properties of such things as light, sound, and force.
Algebra book	Algebra has been called the language of mathematics because it provides a way in which we can arrive at generalized statements or rules for solving mathematical problems.
Book is opened	
Dissolve to montage of numbers	In order to illustrate this we're going to choose a number and work through a series of computations. Although any number could be used, we'll choose thirty six for our example.
Dissolve to '36' in center of screen (Camera zooms back and number moves to upper right hand corner)	
"Add 6" pops on	To this number we're going to add six,
"Multiply by 2" pops on	multiply the answer by two,
"Subtract 8" pops on	Subtract eight,
"Divide by 2" pops on	divide by two,
"Subtract 36" pops on	and finally, take away the original number which, in our case, is thirty six.

	Let's try it---
"36 + 6 = 42"	First we'll add six, giving us an answer of forty two.
"42 x 2 = 84"	Multiply by two and our answer is eighty four.
"84 - 8 = 76"	Subtracting eight leaves us seventy six,
"76 2 = 38"	and dividing by two gives us thirty eight.
"38 - 36 = 2"	By taking away our original number we get two as our final answer.
	Now let's work the problem again only this time we'll write it in algebraic terms.
Dissolve to "n"	Instead of using thirty six we'll use the letter n which can represent any number.
(pop on)	Following the same procedure as before, we'll add six to the number,
(pop on)	multiply this by two,
(pop on)	subtract eight,
(pop on)	divide this answer by two,
(pop on)	and finally, take away the original number. No matter what number
(pop on)	we substitute for "n", the answer will always be two. Our problem has been stated in the form of an equation. It is an expression which asserts the equality of two quantities. In other words, it says, algebraicly, that the general statement which appears on the
Fade out	left is equal to the quantity shown on the right.
Fade in	
Bridge	Algebra provides a foundation of the mathematics used by those who are responsible for building bridges and
Highway	tunnels, highways and railroads;
Telephone lines	for the great network of communication systems;
Water flowing over dam	for irrigation and flood control projects.
Farm buildings	If you live in a rural region of the country, the things you see about you,
Cattle	such as selectively bred cattle,
Corn	hybrid corn,
Machinery	farm machinery--all these are evidence of the application of algebra.
City skyline	No matter where you work or live, algebra

	can be used as a valuable tool in solving even the simplest problems of our modern world. Let's consider a few examples of how algebra is used by people in various walks of life.
Carpenter working at power saw	Mr. Wolf is regarded as one of the most capable and successful carpenters in the town where he lives. His success stems from his ability to complete a job in the shortest possible time and at the lowest possible cost without sacrificing the quality of work or materials. As a carpenter, Mr. Wolf realizes how important algebra is in his work.
Dissolve to model of house	This is a model of a house which Mr. Wolf is building. In the construction of this house, he is planning to use a siding material that is quite expensive. By correctly estimating the amount of siding material he needs, Mr. Wolf knows that he can keept the cost of the house at a minimum.
Dissolve to carpenter reading blueprints.	If he orders too much material, there will be a lot of waste which will mean unnecessary cost. On the other hand, if he doesn't order enough material, the cost will be increased by the time wasted in getting more materials and waiting for it to be delivered.
CU blueprint	In order to estimate the correct amount of siding material that will be needed on the house, Mr. Wolf uses algebraic formulas to find the exact area of all the outside walls. The area of each window and door is also computed and subtracted from the total area.
Dissolve to model of house	It so happens that in building the house Mr. Wolf will need enough siding material to cover exactly seven hundred eighty four square feet of space. From this he is able to order the correct amount of material needed.
Dissolve to carpenter at work	Using formulas is only one of the many ways a carpenter uses algebra in his work. Geometry is another kind of mathematics that is important to a carpenter.

He uses it to find such things as the correct angle of cut on rafters and for making exactly square corners. To a carpenter, algebra and geometry are valuable tools.

Fade out
Fade in
Book: "Egineering as a Career"

Book is opened

Engineering is another field in which algebra is an important tool. In a book entitled Engineering as a Career Albert Himes, an experienced civil engineer writes:

CU print

"The studies which are peculiarly designed for the development of an engineer are mathematics and science. . . .A boy who is to become an engineer cannot absorb too much algebra, geometry, and physics."

Dissolve to: Egineer at drawing table. Camera dollies in for tighter shot showing drawings of bridge.

In planning the construction of a bridge an engineer is faced with many problems. First he must consider the general design of the bridge. This involves a study of the loads to be provided for, width of roadway, and kind of material to be used. Then accurate calculations must be made to determine the stresses and forces that will work on each member of the structure. This, in turn, will determine the form and size of materials to be used.

CU drawings

After the main features have been determined, detailed drawings must be made of each piece to be used in the bridge, and these drawings must show every form and dimension down to the size and location of each rivet and bolt.

Detail of bridge.

The drawings must naturally be accurate so that the separate pieces will fit exactly together when they are put in their final position during the erection of the structure.

More detail
More detail

LS bridge

Algebra is very important to the bridge engineer in solving such problems. Without a knowledge of algebra, accurate calculations that are needed in such work, would be impossible.

Fade out
Fade in
Mechanic working on automobile

Algebra is a practical tool in all kinds of work. Many problems that we encounter can be solved without using

	mathematics at all. But algebra provides a means by which we can solve these problems faster and more accurately. Take Don Delsing for example. Don owns a small, but well-established filling station on the edge of town. He had always been interested in cars and has learned to be a good mechanic. Because
Mechanic walks over to work bench	of his interest in cars and engines, Don was interested in algebra when he was in school, knowing that it would be useful to him later on.
Dissolve to car driving into filling station Don walks up to car and talks to Jack	If asked how algebra has helped him to save time and take the guess work out of some of the problems he encounters, Don would probably recall a situation like the time Jack Fuller drove into his station. It was just before winter,
Don lifting hood on car	and Jack needed radiator protection for the cold weather that was coming. Jack told Don that he had already put four quarts of anti-freeze in the
Jack gets out of car and walks to Don	radiator but knew that it wouldn't be enough to last through the winter. (SYNC SOUND)
	Don: Now then, Jack, to have adequate protection this winter your radiator should have a fifty per cent solution of anti-freeze and water. The capacity of this radiator is sixteen quarts. That means you will need eight quarts of anti-freeze and eight quarts of water.
	Jack: In other words, I will have to drain out four quarts of water and add four quarts of anti-freeze.
	Don: No, it will take much more than that.
	(VOICE OVER)
Dissolve to title "Why will it take more than four quarts?"	Can you see why it will take more than four quarts? (PAUSE)
Dissolve to animated sequence showing solution being drained from radiator and anti-freeze being added.	Jack didn't realize that he would have to add enough anti-freeze to replace what he would drain from the radiator in addition to the four new quarts. If there were already four quarts in the radiator, the anti-freeze would make up four-sixteenths or one-fourth of the solution. This means that the solution

which is in his radiator now is twenty-five per cent anti-freeze. If he drains four quarts of this solution, he will be draining one quart of anti-freeze from the radiator. And if he added four additional quarts there would be only seven quarts of anti-freeze in the solution, making it forty-three and three-fourths per cent instead of fifty per cent.

Dissolve to two shot of Jack and Don

(SYNC SOUND)
Jack: Well it's almost impossible then to determine exactly how much anti-freeze I'll need, isn't it?
Don: No, not at all. Here, let me show you what I mean.
(VOICE OVER)
Don used simple algebra to find the answer to Jack's problem and explained it to him in this way:

Dissolve to animated sequence showing how problem is worked out.

Let "n" represent the number of quarts of anti-freeze that will be added to the radiator. It is a solution of one-hundred per cent anti-freeze.
And, since the capacity of the radiator is sixteen quarts, let the quantity sixteen minus "n" represent the number of quarts that will be left in the radiator after "n" quarts have been drained. This solution is twenty-five per cent anti-freeze. These two quantities add up to sixteen quarts, which is the total number of quarts the radiator will contain when the new solution is mixed. It will be a fifty per cent solution.
Now we can write the equation:
One hundred per cent "n" plus twenty-five per cent times the quantity, sixteen minus "n", equals fifty per cent times sixteen, which says that "n" quarts of one hundred per cent solution plus the number of quarts of the twenty-five per cent solution remaining in the radiator will equal sixteen quarts of a solution that is fifty per cent anti-freeze. The only thing left to do is solve for "n".
(Pause as problem is worked out visually.)

	In other words, Jack must drain five and one-third quarts from the radiator and add an equal amount of anti-freeze to get a fifty per cent solution.
Dissolve to shot showing Don closing hood of car and waving good-bye to Jack. Jack drives away and Don walks into station.	Don Delsing has found that by using algebra in solving such problems he is able to save time and work. It takes the guess-work out of problem-solving and enables him to give his customers efficient and reliable service.
Mechanic working under hydraulic lift.	Don also knows that algebra is necessary to solve some of the mechanical problems he encounters. In re-building motors, he uses it to obtain the highest possible compression ratio of the engine. And in setting the timing of an automobile engine, Don finds that he can do a better job by making use of his knowledge of algebra.
Fade out	
Fade in Algebra book	Algebra is the language of mathematics. But it is also a practical and useful tool. We have pointed out just a few of the ways in which algebra can be used in different types of work. Throughout this series of films we will point out more examples of how mathematics and algebra are important in solving problems that we encounter in everyday life.
Carpenter working at saw	
Engineer at drawing table Chemist writing formulas Mechanic working under hydraulic lift	
Fade out	
Fade in Closing titles	(TITLE MUSIC)

USING EQUATIONS

Titles	(Title Music)
Fade out	
Fade in	
Series of short shots showing time-temperature sign, license plate, graph, parking meter, gas pump, telephone.	Today we are surrounded by mathematics We use it continually . . .often without realizing it.
Dissolve to algebra book	Some of our most useful mathematical concepts are found in elementary algebra.
Camera zooms in slowly	Here we find ideas and operations that are directly helpful in solving some of our everyday problems. Algebra has been called the shorthand of mathematics because it provides a way in which we can state mathematical problems in a concise form.
$y = x + 2$	This equation, for example, is a symbolic statement which says that the value of y is always two units greater than the value of x.
Montage of equations	Many problems which we encounter in every day life can be stated as algebraic equations. In fact, it would be impossible to solve some problems without using equations. Let's consider some examples of how algebraic equations are used in different types of work.
Secretary working at desk. She turns to work at typewriter.	A common problem in secretarial work is to find the center space of a typewritten
CU of typewriter. Carriage is moved.	page. This is done by finding the space which is half-way between the left and right margins of the page.
	It is a mathematical problem, and by stating it as an algebraic equation you will see that the procedure for finding the center space can be simplified.
Animated sequence in which equation pops on.	If x represents the left margin and y represents the right margin, subtract x from y to find the range of spaces between margins. Divide this by two to find the space half-way between the two margins. Then add x to find the number of the space.
"x" changes to 15.	Thus, if the left margin were set at fifteen and the right margin at

"y" changes to 75	seventy five, the center space would be forty five. You will notice, however, that by simplifying our equation we can simplify the procedure for finding the center space.
Animated sequence of equation being simplified.	(Pause while problem is worked out visually.) Now we can state that the center space of a typewritten page is equal to the left margin plus the right margin, divided by two.
Dissolve to Nurse reading from sheet of paper. MS- Nurse reaches into cabinet for bottle	Sometimes we use equations to find the value of unknown quantities. This is Miss Easton, a nurse at city hospital. She has been told to prepare a two per cent dextrose solution for intra-
LS--Nurse writing on paper.	vaneous use. The hospital does not stock a two per cent solution, but does have a five per cent solution.
CU--equation being worked out.	In reducing five hundred cubic centimeters of this to a solution that is two percent dextros, Miss Easton uses an equation.
LS--Nurse walks out of frame.	By solving for x she candetermine how much water she will need to add to this five per cent solution.
Fade out Fade in Flood scenes	Algebraic equations have even been used to save lives. During a flood along the Cedar River in Iowa, hydraulic engineers used a simple equation to predict the height of the flood crests at Waterloo and Cedar Rapids, Iowa.
Flooding river	The discharge or amount of water which flows through a river channel is equal to the cross-sectional area of the river, times the velocity or speed at which the river is moving.
Q = AV	This can be expressed by the equation, Q equals A times V, where A is the cross-sectional area of the river, and V is the velocity of the water.
Drawing showing cross-section of river divided into subsections.	The cross-sectional area of a river can be measured by dividing the total area into a number of sub-sections. The sum of these separate areas is equal to the toal cross-sectional area.

Men taking measurements from bridge.	The velocity of the river can be measured by instruments which record the speed in feet per second.
Q = AV	When the area of the cross-section and the velocity of the river are known, the equation, Q equals A times V, will give the amount of water flowing through the river channel in feet per second.
Map	In predicting the flood crest at Waterloo, Iowa, measurements were taken upstream
77,000 pops on	and the peak discharge was found to be seventy seven thousand cubic feet of water per second.
Sign on office door	From previous flood data, the United States Geological Survey Office has
Engineer takes graph from file	compiled a graph or rating curve which is used to predict the height of the river in Waterloo for any given discharge.
Rating curve	Since the estimated discharge was seventy seven thousand cubic feet per second, the river was predicted to crest at twenty two feet in Waterloo, which is seven feet above the flood stage.
Flood scenes	Residents of the city were warned of this and thousands of homes were evacuated saving many lives.
Map	After the flood had passed through the city of Waterloo, additional measurements were taken at downstream sites and it was discovered that the peak discharge had
73,000 pops on	dropped to seventy three thousand cubic feet per second.
Rating curve	Knowing this, the Geological Survey Office predicted the height of the river crest for Cedar Rapids. The river was predicted to crest at twenty feet in Cedar Rapids, seven feet above flood stage.
Flood scenes	Again, residents of the city were warned and preparations were made to keep the flooding river in its banks.
Q = AV	As you can see, although this equation appears to be quite simple, it has some
Fade out Fade in	important applications.
Aerial shot of highway patrol plane	Another important use of equations is found in the Iowa Highway Patrol's air-to-ground speed-check system.
Aerial shot of car moving down highway	By recording the time it takes an automobile to travel the distance between

Dissolve to equation	two lines, patrolmen can calculate the speed of the car from this equation. V represents the velocity or speed of a vehicle, where D is the distance between the two lines, and T is the time it takes to travel that distance.
Patrolman in plane watching traffic on ground below	This is patrolman Paul Foster. He flies a spotter-plane for the Iowa Highway Patrol. From his plane he records the time it takes a vehicle to travel the distance between the two lines on the highway.
Car crossing first white line	
CU--stopwatch being started	The stopwatch which patrolman Foster uses measures the time in tenths of a second. When a car or truck crosses the second line he records the time with his watch. He then refers to a chart which is based on the equation, V equals D divided by T. It lists the rate of speed for each time interval. From this chart, patrolman Foster can immediately determine the average speed at which the automobile was travelling between the two lines.
Car crossing second white line	
CU--stopwatch being stopped. Watch is removed from frame to show chart.	
Patrolman talking on radio	This information is radioed to Patrolman Joe Smith on the ground. Whether or not patrolman Smith takes further action will depend, of course, on how fast the car was travelling.
Patrolman in car	
Chart	The chart which patrolman Foster uses resembles a table of values that we might use in plotting a graph. If these values are plotted, we can picture the the time-speed relationship for a given distance. Graphs are often used to visualize equations in this way. By using a graph, we can gain a better understanding of what equations represent.
Dissolve to graph of equation	
Formula	For example, this formula gives the power which is produced when a shaft is driven by a leather belt. V represents the velocity at which the leather belt is moving. It might be natural to assume that more power would be produced when the velocity of the belt is increased.
Dissolve to graph	When we graph the equation, however, we find that the power is increased only until the velocity reaches five thousand seven hundred feet per second. If the belt is driven faster than this the

	power actually decreases. Just as graphs are used to picture equations, equations are sometimes used to
Graph of circle	mathematically represent lines and curves. A circle, for example, can be
Equation pops on	represented by this algebraic equation. Many of our laws of physics were dis- covered by recording observations on a graph and then finding an equation to express the observed relationship.
Graph of Parabola Dissolve to Cubical Parabola Dissolve to Semi-cubical parabola Dissolve to Hypocyloid of Four Cusps Dissolve to Folium of Descartes Dissolve to Strophoid Dissolve to Cassinian Curve	Some of the curves and equations used in higher mathematics are quite common and have been given special names. A seventeenth century French mathematician by the name of Descartes was the first to introduce the procedure which showed that properties of curves could be expressed by algebraic equations. Descartes' work during the seventeenth century opened the door to many of the scientific achievements of our modern world.
Dissolve to Parabola Match dissolve to suspension bridge Graph of ellipse Match dissolve to elliptical-shaped water tower.	The graphing of some equations results in curves which are very familiar to us. (Pause while matched dissolves are shown) The way in which these equations fit the shape of familiar objects is not an accident. In some cases the design of structures is determined by equations in order to make construction of them possible.
Fade out Fade in Secretary at typewriter	An algebraic equation is nothing more than a symbolic statement. But as you
Flood scene	have seen equations have many practical applications. Perhaps you would like to see more examples of how algebraic
Patrolman in plane Nurse	equations are used. Most people like to talk about their work. Ask them how they use algebra and mathematics in solving some of their everyday
Fade out Fade in Titles	problems. (Title Music)

RATIO AND PROPORTION

Title	(Title Music)
Fade Out	
Fade In	
LS--Flag	Although this flag is very familiar to us, few people are aware of the fact that it has anything to do with algebra.
CU--Flag	The algebraic concept of ratio and proportion is used to determine the size of this and every other United States flag. A federal law of nineteen-twelve states that the ratio of length to height for the official United States flag must be one-point nine to one.
Dissolve to ratio	A ratio is a comparison of two numbers by division. For example, if there are half as many girls in class as there are boys, the ratio of girls to boys is one to two or one-half. As you can see, a ratio is a fraction. However, sometimes ratios are expressed in different ways.
Visual showing half as many girls as boys	
½ pops on	
1:2	
.50	
50%	
a/b = c/d	When two ratios are equal to one another they form a proportion. In other words, if the ratio of a to b to equal to the ratio of c to d, we say that a, b, c, and d are proportional.
2/3 = 28/x	Since a proportion is an equation, when three quantities of a proportion are known the value of the unknown quantity can be found by solving the equation. (Pause while problem is worked out visually.)
animated sequence of problem being worked out	
Dissolve to CU of flag	Let's go back to our example of the flag. We said that the ratio of length to height of the flag is one-point-nine to one. Suppose we want to use a flag which is twenty inches high. By solving the equation we can find the length of the flag.
proportion	This concept of ratio and proportion is one of the most useful ideas found in elementary algebra. It is helpful in solving many of our everyday problems.
Dissolve to housewife in kitchen reading recipe book.	

Recipe

MS--housewife writing out problem

CU--problem being written out and solved.

Recipe

Title: Stop film here
Answers are shown one at a time

Dissolve to tractor pulling wagon through feed lot
Feed being mixed in wagon

Feed coming out of wagon into feeder

proportion

A housewife often uses proportions to change the quantity of recipes. Mrs. Cushman, for example, has five quarts of strawberries that she wants to make into strawberry jam. The recipe she is following calls for two quarts of strawberries and seven cups of sugar. By using five quarts of strawberries, Mrs. Cushman is increasing the recipe at a ratio of five to two. Thus, the amount of sugar will have to be increased at the same ratio.
In order to determine how much sugar she must use with five quarts of strawberries, Mrs. Cushman uses this proportion. By solving the equation for x, she can find the amount of sugar she will need.
Here is a recipe for three dozen cookies. Suppose you want to make four dozen cookies from this recipe. In other words, you want to increase the recipe at a ratio of four to three. How much of each ingredient will you need? Write out this recipe on a piece of paper and then, while the film is stopped, use proportions to determine how much you must increase each ingredient. (Shot held for ten seconds)
If we increased the recipe at a ratio of four to three, we would need two and two-thirds cups of shortening, five and one-third cups of flour, one and one-third teaspoons of baking powder, two cups of sugar and four eggs.
The use of proportions to increase quantities is found in many types of work.
This farmer uses proportions in adding a concentrate to his cattle feed. He has found that he can obtain the most efficient blend of cattle feed by mixing protein concentrate with corn at a ratio of one to eight. Thus, if he uses twenty-four hundred pounds of corn, he can determine how much concentrate must be added from this proportion.

Dissolve to CU of lumber being measured.	Proportions can also be used as a means of indirect measurement. Many times we need to know the size of objects. If the object can be measured easily, a ruler or tape line might be used. However,
Trees River	there are some objects which can't be measured this way, such as the height of trees or the distance across a river. These can be measured indirectly by using proportions and a few simple rules of geometry.
Dissolve to similar triangles.	In geometry we learn a rule which states that the sides of two right triangles are proportional when an acute angle of one triangle is equal to an acute angle of the other.
Dissolve to proportion AB changes to 2 BC changes to 6 DE changes to 3	In other words, if angle A is equal to angle D, then the ratio of line AB to line BC is equal to the ratio of line DE to line EF. Thus, if AB equals two inches, BC equals six inches and DE equals three inches, by solving the proportion we know that line EF is equal to nine inches.
River Boy building raft with logs	Suppose we were planning to build a bridge across this river. How could we measure the distance? We could, of course, build a raft and stretch a rope across the river, as this fellow
Dissolve to boy pushing raft into river and climbingaboard.	is planning to do. But building a raft involves a great deal of time and work. And even after the raft is completed, we can never be sure that it will take us
Dissolve to LS showing boy on raft in middle of river. Boy loses his balance and falls into water.	to the other side. As you can see this procedure has many disadvantages. Besides, it is much easier and faster if we use algebra.
Dissolve to diagram showing similar triangles.	By laying out two right triangles and using a proportion, we can measure the unknown distance indirectly. Suppose we find that the distance between A and D is equal to twenty yards, the distance between D and E is fifteen yards, and the distance between A and
Proportion	B is fifty yards. To find the distance between B and C we can use this proportion.

Dissolve to boy climbing out of water
Trees

Visual showing two similar right triangles.

Dissolve to proportion
Fade out
Fade in
Architect at drawing table

CU of drawings

MS of architect

CU of floor plan

LS of architect at table

Dissolve to television set

Production scene in TV studio

Artist working on visual card.

You see? It's much easier when we use algebra.
Foresters often use proportions in this way to indirectly measure the height of trees. For example, suppose that a shadow of a tree is thirty-two feet long when an object which is five feet tall, casts a shadow that is eight feet long. By using this proportion we can find the height of the tree.

An architect uses the concept of ratio and proportion in several ways. In planning a house, an architect uses drawings to visualize his ideas. To be meaningful, these drawings must show each part of the structure in the correct proportion. It would be ridiculous, of course, if the drawings were the same size as the house itself; so ratios are used to make scale drawings which are proportional to the actual dimensions of the structure. This floorplan for example, is drawn to a scale in which one-fourth inch represents one foot, a ratio of one to forty-eight.
It would be impossible for an architect to visualize the final appearance of a house if ratios were not used to show the correct proportions.
The concept of ratio and proportion lends itself to many practical applications. Although you may spend several hours every week looking at this screen, you probably haven't realized that ratio and proportion play an important part in the planning of many things you see. You will notice that the ratio of height to width of the television screen is a ratio of three to four. In television this is known as the aspect ratio. This aspect ratio is important throughout the many steps of preparation that are needed for a television program. All visual materials that are used must be designed and constructed with this ratio in mind.

Director showing actor where to stand	In planning the camera shots, a television director uses the aspect ratio to find the best positions for the cameras and to tell the actors or announcers where they must stand.
Designer at drawing table.	In designing the scenery, plans similar to those used by an architect are drawn to scale. The drawings are usually
CU of drawings	made to a scale in which one-fourth inch represents one foot of the actual size, a ratio of one to forty-eight.
Men setting up scenery	These scale drawings are closely followed in constructing the scenery and arranging it on the floor of the television studio.
TV gray scale chart	After the scenery is constructed, it must be painted. Again ratios are used, this time to determine what shades of paint should be used. Samples of paint
Samples are laid against scale.	are compared with a "gray scale" which shows the range of shades that can be satisfactorily reproduced by the television cameras.
	The ratio between adjacent steps on this scale is one-point-six to one. This means that each shade of gray on this scale reflects one-point-six times more light than the next darker shade.
TV production scene	Ratios and proportions are used in many and varied ways in television; but few
TV director talking over inter-com from control room. "On-the-Air"light blinks on.	people realize this when they are relaxing at home, watching their favorite program.
TV production scene	
Fade out	
Fade in	
Algebra book	The concept of ratio and proportion is one of the more advanced topics in elementary algebra. And, as you have seen, it can be a very useful concept.
Dissolve to carpenter	Throughout this series of films we have
Chemist	pointed out examples of how algebra is
Mechanic	a tool which we use in solving many of
Physicist	our everyday problems. But the field
Secretary	of mathematics includes much more than
Patrolman	algebra. Algebra is only the beginning,
Nurse	a very important beginning. When you
Flood scene	begin to study other kinds of mathematics
Architect	you will see why algebra is called the

Homemaker
TV scene designer
TV director
TV production scene
Fade out
Fade in
Titles

"language of mathematics." You will also see how mathematics, from arithmetic to calculus, plays such an important part in the activities of our modern world.

(Title Music)

APPENDIX B

EXPERIMENTAL BOOKLETS

ALGEBRA AND ITS USES

On January 31, 1958 the United States launched a Jupiter-C rocket putting its first man-made satellite into orbit around the earth. The purpose of this satellite, which was later named Explorer I, was to gather information concerning the many mysteries of outer space. Launching rockets into outer space is no longer a novelty. The number of problems which space scientists face has been minimized by the vast amount of research that has been carried out in the past few years.

Many of the problems which confront space scientists are solved with the help of simple algebra. Of course a knowledge of algebra alone is not enough to put a satellite into orbit. Space scientists need to use mathematics far more advanced than first-year algebra. But algebra is the foundation for these mathematics just as it is the foundation for other areas of study.

Algebra is often called the language of mathematics because it provides a way in which we can arrive at generalized statements or rules for solving mathematical problems. A well-known mathematical trick, which can be used to illustrate this, runs as follows: "Think of a number. Add six to it. Multiply your answer by two. Subtract eight. Divide by two. Finally, subtract the number you first thought of." No matter what number you choose, the answer is always 2. Why?

Perhaps we can understand the problem better if we write it in algebraic terms. Instead of choosing a number, we'll choose the letter n which can represent any number. Now follow the same procedure:

Add 6. . . . . n + 6
Multiply by 2. . . . . .2n + 12
Subtract 8 . . . .2n + 4
Divide by 2. . . . . n + 2

Take away the original number (n) the answer is . . .2. We can express the whole process, and the fact that the answer is always 2, by writing the single equation:

$$\frac{2\,(n + 6) - 8}{2} - n = 2.$$

We have already stated that algebra provides a foundation for other areas of study. Chemistry, for example, requires a knowledge of algebra in order to understand the relationships between elements. The study of physics requires knowledge of algebra in order to understand the properties of such things as light, sound, and force. Algebra is used by those who are responsible for building bridges and tunnels, highways and railroads; for the great network of communication systems; for irrigation and flood control projects. If you live in the country the things you see about you, such as terraced slopes and contour plowing, farm machinery, hybrid corn, selectively bred cattle--all these are evidence of the application of algebra. No matter where you live or what you do, algebra is a valuable tool in solving even the simplest problems of our modern world.

Let's consider how a carpenter might make use of algebra. In order to be successful at carpentry, one must be able to complete a job quickly and at a minimum cost without sacrificing the quality of work or materials.

Suppose you were a carpenter and were in the process of building a house. The plans of the house call for a siding material that is quite expensive. By correctly estimating the amount of siding material that is needed you could keep the cost of the house at a minimum. If you ordered too much material, there would be a lot of waste which would mean unnecessary cost. On the other hand, if you didn't order enough material, the cost would be increased by the time wasted in getting more material and waiting for it to be delivered. By using algebraic formulas you would be able to find the exact area to be covered with siding. From this, the correct amount of siding material that would be needed could be estimated.

Using formulas is only one of the many ways a carpenter uses algebra in his work. He uses other kinds of mathematics too, such as geometry, to find the correct angle of cut on rafters and for making exactly square corners. To a carpenter, algebra and geometry are very valuable tools.

Engineering is another field in which algebra is important. In a book entitled Engineering as a Career, Albert Himes, an experienced civil engineer, writes: "The studies which are peculiarly designed for the development of an engineer are mathematics and science. . . .A boy who is to become an engineer cannot absorb too much algebra, geometry, and physics.

In planning the construction of a bridge an engineer is faced with many problems. First he must consider the general design of the bridge which involves a study of the loads to be provided for, width of roadway, and kind of material to be used. After the main features have been determined detailed drawings must be made of each piece to be used in the bridge, and these drawings must show every form and dimension down to the size and location of each rivet and bolt. The drawings must naturally be accurate so that the separate pieces will fit exactly together when the bridge is erected. Algebra is very important to the bridge engineer in solving such problems. Without a knowledge of algebra, the accurate calculations needed in this work would be impossible.

Of course, some problems encountered in certain jobs can be solved without using algebra or other mathematics; but algebra provides a means by which we can solve many of these problems faster and more accurately.

Fred Martin, for example, owns a small but well-established filling station on the edge of town. Fred was interested in algebra when he was in school because of his interest in cars and engines. If asked how algebra has helped him to save time and take the guess-work out of some of the problems he encounters, Fred would probably recall a situation like the time Jack Fuller drove into his station. It was just before winter, and Jack needed some anti-freeze for the radiator on his car. Jack had already put 4 quarts of anti-freeze in the radiator, but knew that it wouldn't be enough to last through the winter. The solution in the radiator had to be at least 50% in order to have adequate protection. The radiator on Jack's car had a capacity of 16 quarts, meaning there should be 8 quarts of water and 8 quarts of anti-freeze in the solution. Since he had already put 4 quarts of anti-freeze in the radiator Jack thought he would simply have to drain 4 quarts from the radiator and add 4 quarts of anti-freeze. But Fred told him that it would take more than four quarts in order to get a 50% solution. Can you see why?

Jack didn't realize that he would have to add enough anti-freeze to replace what would be drained from the radiator in addition to the 4 new quarts. If there were 4 quarts of anti-freeze in the 16-quart radiator, it would be a 25% solution. By draining 4 quarts of this solution, the amount of anti-freeze drained from the radiator would amount to 1 quart; and if 4 additional quarts were added, there would be only 7 quarts of anti-freeze in the solution, making it 43.75% instead of 50%.

Jack thought it would be impossible to determine exactly how much anti-freeze he would have to add, but Fred showed him how the problem could be solved by using simple algebra.

Let n = the amount of anti-freeze to be added to the radiator. (100% solution)

Then, (16 - n) = the amount of anti-freeze left in the radiator. (25% solution)

16 = the number of quarts in the final solution. (50% solution)

From these statements the following equation can be written:

$$100\%n + 25\% (16 - n) = 50\% (16),$$

which says that n quarts of a 100% solution plus the number of quarts of the 25% solution remaining in the radiator will equal 16 quarts of a solution that is 50% anti-freeze. By solving the equation, we can see that Jack would have to drain 5.33 quarts from the radiator and add an equal amount of anti-freeze to get a 50% solution.

Fred Martin has found that by using algebra in solving such problems he is able to save time and work. It takes the guess-work out of problem-solving and enables him to give his customers the best possible service.

Fred also knows that algebra is necessary to solve some of the mechanical problems he encounters. In re-building motors, he uses it to obtain the highest possible compression ratio of the engine. And in setting the timing of an automobile engine, Fred finds that he can do a better job by making use of his knowledge of algebra.

Yes, algebra is not only the language of mathematics, it is also a practical and useful tool. We have pointed out just a few of the many examples which show how algebra is important in solving problems that we encounter in everyday life. It is used by people in all types of work ranging from housekeeping to engineering. Perhaps you have wondered how algebra can be used in other activities. If so, you might find out by talking with those who are engaged in the type of work in which you are interested.

USING EQUATIONS

You are probably aware of the fact that many activities of our modern world are becoming more and more dependent on mathematics. You may not realize, however, that some of our most useful mathematical concepts are found in elementary algebra. Here we find ideas and operations that are directly helpful in solving some of our every-day problems.

Algebra has been called the "shorthand" of mathematics because it provides us with a method of using symbols to state mathematical problems in a concise form. For example, if we want to say that the value of one variable is always two units greater than the value of a second variable, we can express the whole statement by the simple equation,

$$y = x + 2.$$

Many problems which we encounter can be simplified if they are stated as algebraic equations. In fact, some problems would be impossible to solve without using equations. Let's consider a few examples of how we use this algebraic concept in various types of work.

A common problem in secretarial work is to find the center space of a typewritten page. If you have ever used a typewriter you will remember that each space is numbered, and that there are a certain number of spaces across the page. To find the center space of a typewritten page it is necessary to find the space which is half-way between the left and right margins of the page.

Suppose you were typing a letter with the left margin set at 15 and the right margin set at 75. How would you find the center space? Take a few moments to figure this and note the procedure that you follow.

To find the center space with the margins at 15 and 75, it is natural to procede as follows:

1. Subtract 15 from 75 to find the range of spaces between margins.
2. Divide this by two, to find the number of spaces half-way between the two margins.
3. Finally, add the result of step #2 to 15 in order to find the number of the center space.

Although this appears to be the fastest and easiest procedure to follow, by stating the problem as an algebraic equation you will see that the procedure can be simplified.

Let x represent the number of the left margin and y represent the number of the right margin. The entire procedure listed above can then be stated by the equation, $C = \frac{y - x}{2} + x.$

You will notice, however, that this equation can be simplified:

$$C = \frac{y - x}{2} + x.$$
$$2C = y - x + 2x.$$
$$2C = 2x - x + y.$$
$$2C = x + y$$
$$C = \frac{x + y}{2}$$

Now we can state that the center space of a typewritten page is equal to the left margin plus the right margin divided by 2. This procedure is not obvious until it is demonstrated by using an algebraic equation.

Sometimes we use algebraic equations to find the value of unknown quantities. Nurses often use equations this way. Suppose you were a nurse and were told to prepare a 2% dextrose solution for intravenous use. The hospital where you work does not stock a 2% solution, but does have a 5% dextrose solution To prepare a 2% dextrose solution, you would have to add a certain amount of distilled water to the 5% solution. In order to determine how much water you would need to add, it would be necessary to state the problem in the form of an algebraic equation. If 500 cubic centimeters of the 5% solution were used, the problem could be stated by the equation,

$$2\%(500 + x) = 5\%(500).$$

By solving for x, you could find the unknown amount of water that you would need to add to the 5% solution.

Algebraic equations have even been used to save lives. During a flood along the Cedar River in Iowa, hydraulic engineers used a simple equation to predict the height of the flood crests at Waterloo and Cedar Rapids, Iowa.

The discharge or amount of water flowing through a river channel is equal to the cross-sectional area of the river times the velocity or speed at which the river is moving. This can be expressed by the equation,

$$Q = AV,$$

where A is the cross-sectional area of the river and V is the velocity.

The cross-sectional area of a river is measured by dividing the total area into a number of sub-sections. The sum of these separate areas is used as the total cross-sectional area (See Figure 1).

Engineers measure the velocity of a river by instruments which record the speed in feet per second. When the area and the velocity are known the equation,

$$Q = AV,$$

will give the amount of water flowing through the river channel in feet per second.

In predicting the flood crest at Waterloo, Iowa, hydraulic engineers took measurements of the Cedar River at upstream sites. The peak discharge along the river was found to be 77,000 cubic feet of water per second.

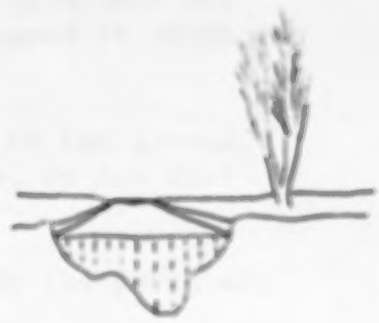


Figure 1

From previous flood data, the United States Geological Survey Office was able to predict the height of the river in Waterloo for a discharge of 77,000 cubic feet per second. The river was predicted to crest at 22 feet in Waterloo which is 7 feet above flood stage. Residents of the city were warned of this and thousands of homes were evacuated, saving many lives.

After the flood had passed through the city of Waterloo, additional measurements were taken at downstream sites to predict the height of the flood crest for Cedar Rapids. The river was predicted to crest at 20 feet in Cedar Rapids, 7 feet above flood stage. Again residents of the city were warned and preparations were made to keep the flooding river in its banks.

As you can see, although the equation, $Q = AV$ is a very simple one, it has some important applications.

Another important use of equations is found in the Iowa Highway Patrol's air-to-ground speed-check system. You have probably noticed the pairs of white lines painted across several highways in Iowa, but did you realize that these lines had anything to do with algebra?

By recording the time it takes an automobile to travel the distance between these lines, patrolmen can calculate the speed of the automobile from the equation, $V = \frac{D}{T}$.

V represents the velocity or speed of a vehicle when D is the distance between the two lines, and T is the time it takes to travel that distance.

From an airplane, a patrolman uses a stopwatch to record the time it takes a vehicle to cross the two lines. He then refers to a chart which is based on the equation,

$$V = \frac{D}{T}.$$

The chart lists the values of V for each value of T. From this the patrolman in the plane can immediately determine the speed at which the automobile was traveling between the two lines.

This information is radioed to another patrolman on the ground. Whether further action is taken will depend, of course, on how fast the automobile was traveling.

A section of the chart, similar to the one used by the patrolman in the airplane, is shown below:

T (seconds)	V (miles per hour)
5.6	80.36
5.7	78.95
5.8	77.59
5.9	76.27
6.0	75.00
6.1	73.77
6.2	72.58
6.3	71.43
6.4	70.31

By using this chart as a table of values for a graph, we can picture the time-speed relationship for the given distance (see Figure 2).

Graphs are often used to visualize equations in this way. By using a graph we can gain a better understanding of what equations represent For example, the formula,

$$P = 364V - \frac{V^3}{270{,}000},$$

gives the power (P) which is produced when a shaft is driven by a leather belt. V represents the velocity at which the belt is moving in feet per second.

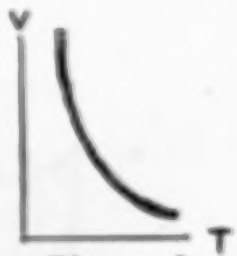


Figure 2

It is natural to assume that more power would be produced when the velocity of the belt is increased. But draw a graph of the equation, taking V for values between 0 and 8,000. You will find that P rises until V reaches 5,700. If the belt is driven faster than 5,700 feet per second, the power which is produced is not more, but less.

Just as graphs are used to picture equation, equations are sometimes used to mathematically represent lines and curves. A circle, for example,

can be represented by the equation,

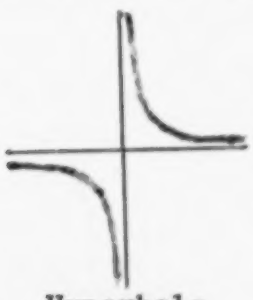
$$x^2 + y^2 = r^2,$$

where r is the radius.

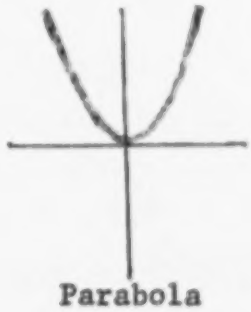
A seventeenth century French mathematician by the name of Descartes was the first to introduce the procedure which showed that properties of curves could be expressed by algebraic equations. He demonstrated that certain relationships between points on a curve correspond with certain relationships between numbers.

Descartes' work during the seventeenth century opened the door which led to many of the scientific achievements of our modern world.

Many of our laws of physics were discovered by recording observations on a graph and then finding an equation to express the relationship between variables. Some of the curves and equations in higher mathematics are used so often that they have been given special names. A few of these are shown below:



Hyperbola



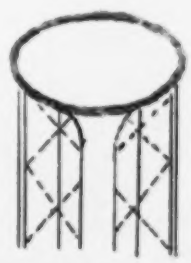
Parabola

Hypocycloid of Four Cusps

The graphing of some equations results in curves which are very familiar to us. Notice the following curves:

$x^2 + y^2 = r^2$

$y = ax^2$



$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$

The way in which these equations fit the shape of familiar objects is not an accident. In some cases the design of structures is determined by equations in order to make construction of some of them possible.

An algebraic equation in nothing more than a symbolic statement; but equations have many practical applications. Perhaps you have wondered how algebraic equations are used in other activities. Most people like to talk about their work. Ask them how they use algebra and mathematics in solving some of their everyday problems.

RATIO AND PROPORTION

The next time you look at a flag of the United States, notice its dimensions. Perhaps you have a flag hanging in your classroom. Approximately how long and how high would you judge it to be? If it is convenient, you might even measure it to find the exact dimensions.

You may be surprised to learn that the algebraic concept of ratio is involved in determining the dimensions of every United States flag. A federal law states that the ratio of length to height for the official United States flag must be 1.9. This means that no matter what the size of the flag, the length must be 1.9 times the height.

A ratio is a comparison of two numbers by division. For example, if there are one-half as many girls in class as there are boys, we say that the ratio of girls to boys is 1 to 2 or $\frac{1}{2}$.

As you can see, a ratio is a fraction. However, sometimes ratios are expressed in different ways. The ratio of 1 to 2, for example, can be stated by any one of the following systems of notation:

$$\frac{1}{2} = 1:2 = 50 = 50\%$$

If two ratios are equal to one another, they form a proportion. In other words, if the ratio a:b is equal to the ratio c:d, we say that a, b, c, and d are proportional. If two ratios are not equal, the quantities are not proportional. Can you see which of the following are proportions and which are not?

$$1/2 = 4/8, \quad 1/3 = 3/8, \quad 2/6 = 3/9.$$

Since a proportion is an equation, when three quantities of a proportion are known the value of the unknown quantity can be found by solving the equation.

Let's go back to our example of the flag. We said that the ratio of length to height of the flag is 1.9 to 1, or simply, 1.9. Suppose we want to use a flag 20 inches high. What will the length of the flag be? To solve this, we can state the problem as follows:

$$\frac{1.9}{1} = \frac{x}{20}$$

By solving this equation, you will see that a flag 20 inches high will be 38 inches long.

The concept of ratio and proportion is one of the most useful ideas found in elementary algebra. It is helpful in solving many of our everyday problems. A housewife, for example, often uses proportions to change the quantity of recipes.

Suppose you wanted to make four dozen cookies from a recipe which is for only three dozen cookies. In other words, you want to increase the recipe at a ratio of 4 to 3. You would have to increase the amount of each ingredient by the same ratio. Use the recipe below as an example and find out how much of each ingredient you would need if you increase the recipe at a ratio of 4 to 3. When you have finished, check your answers with those found on the last page. (Please do not write in this booklet.)

Recipe for 3 dozen cookies

2 cups shortening	1½ cups sugar
4 cups flour	3 eggs
1 tsp. baking powder	

The use of porportions to increase quantities is found in many types of work. A farmer, for example, may find that he can obtain the most efficient blend of cattle feed by mixing a feed concentrate with corn at a ratio of 1 to 8. If he uses 1600 pounds of corn, the following proportion can be used to determine how many pounds of feed concentrate he will need:

$$1/8 = \frac{x}{1600}$$

Proportions can also be used as a means of indirect measurement. Many times we need to know the size of an object. If the object can be measured easily, a yardstick or tape line is used. However, there are some objects which can't be measured this way, such as the height of a tree or the distance across a river. These can be measured indirectly by using proportions and a few simple rules of geometry.

In geometry we learn a rule which states that the sides of two right triangles are proportional when an acute angle of one triangle is equal to an acute angle of the other. In other words, if angle A (in figure 1) is equal to angle D, then the ratio of line AC to line AB is equal to the ratio of line DF to line DE. Thus, if AC is 6 inches, AB is 2 inches, and DF is 9 inches, we know by using the proportion,

$$\frac{6}{2} = \frac{9}{x},$$

that line DE is equal to 3 inches.

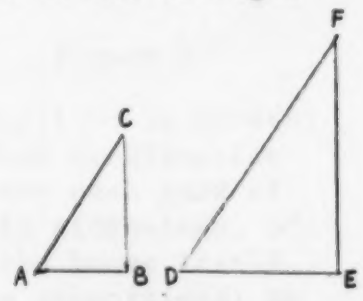


Figure 1

Suppose we were planning to build a bridge and wanted to know the distance across a river. Let's look at how we might use a proportion

to measure the unknown distance. If the drawing in figure 2 represents the river, our problem would be to find the distance between B and C. We could, of course, build a raft, stretch a rope between these two points, and measure the length of the rope; but this might have certain disadvantages, such as slipping off the raft. Besides, you will see that it is much easier and faster if we use algebra. By laying out two right triangles, as shown in figure 2, and by using a proportion we can measure the distance indirectly.

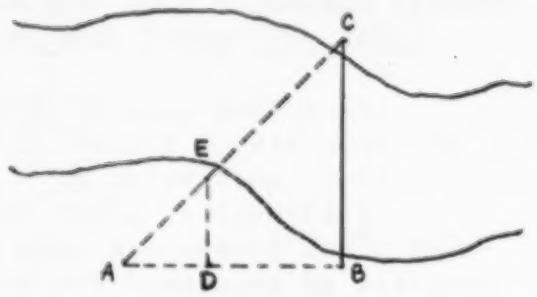


Figure 2

Suppose we find that the distance between A and D is 4 yards, the distance between A and B is 50 yards, and the distance between D and E is 9 yards. To find the unknown distance between B and C we can use the proportion,

$$\frac{4}{9} = \frac{50}{x}.$$

Foresters often use proportions in this way to indirectly measure the height of trees. For example, suppose that a shadow of a tree is 32 feet long while an object which is 5 feet tall casts a shadow that is 8 feet long. (See figure 3.) By using the proportion,

$$\frac{5}{8} = \frac{x}{32},$$

we can find the height of the tree.

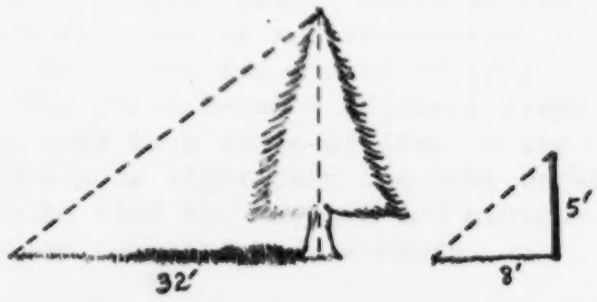


Figure 3

An architect uses the concept of ratio and proportion in several ways. In planning a house, an architect uses drawings to visualize his ideas. To be meaningful, these drawings must show each part of the structure in the correct proportion. It would be ridiculous, of course, if the drawings were made the same size as the house itself. So, ratios are used to make scale drawings which are proportional to the actual dimensions of the structure. For example, if ¼ inch on the scale drawing is equal to one foot of the actual size, the dimensions are at a ratio of 1 to 48. It would be impossible for an architect to visualize the final appearance of a house if ratios were not used in this way to show the correct proportions.

The concept of ratio and proportion lends itself to many practical applications. Although you may spend several hours every week watching television, you probably haven't realized that this algebraic concept plays an important part in the planning of many things you see.

The next time you look at a television screen, notice its dimensions. You will see that the ratio of height to width of the television picture is a ratio of 3 to 4. In television, this is known as the "aspect ratio " This aspect ratio is important throughout the many steps of preparation that are needed for a television program. All visual materials that are used must be designed and constructed with this ratio in mind. In planning the camera shots, a television director uses the aspect ratio to find the best position for the cameras and to tell the actors or announcers where they must stand.

Scale drawings, similar to those used by an architect, are also used in the preparation of many television shows. These drawings are usually made to a scale in which ¼ inch represents 1 foot of the actual size, a ratio of 1 to 48. These scale drawings are closely followed in constructing the scenery and arranging it on the floor of the television studio.

After the scenery is constructed, it must be painted. Again ratios are used, this time to determine what shades of paint should be used. Samples of paint are compared with a "gray scale" which is the range of shades between white and black that can be satisfactorily reproduced by the television cameras. There are ten shades of gray in a standard television gray scale. The ratio between adjacent steps on this scale is 1.6 to 1. This means that each shade of gray in the television gray scale reflects 1.6 times more light than the next darker shade. Scene designers use this ratio to find the maximum and minimum amounts of contrast they can have between two pieces of scenery.

Examples of how ratios are used in planning a television show are many and varied; but few people realize this when they are relaxing at home, watching their favorite television program.

The concept of ratio and proportion is one of the more advanced topics in elementary algebra and, as you have seen, it is a very useful concept.

Throughout your study of algebra, you have seen that algebra is a tool which we use in solving many of our everyday problems. But the field of mathematics includes much more than algebra. Algebra is only the beginning, a very important beginning.

When you begin to study other kinds of mathematics, such as geometry, trigonometry and calculus, you will see why algebra is often called the "language of mathematics." You will also see how mathematics, from arithmetic to advanced calculus, plays an important part in the activities of our modern world.

Answers to problem on page 3:

2 and 2/3 cups shortening
5 and 1/3 cups flour
1 and 1/3 tsp. baking powder
2 cups sugar
4 eggs

APPENDIX C

TEACHER RATING FORM.

Student's name:_____

How would you rate this student's general behavior in algebra class?

ambitious___:___:___:___:___:___:___lazy

interested___:___:___:___:___:___:___disinterested

highly motivated___:___:___:___:___:___:___not at all motivated

How would you rate the work this student does for your algebra class?

neat___:___:___:___:___:___:___messy

prompt___:___:___:___:___:___:___late

complete___:___:___:___:___:___:___incomplete

How much does this student participate in algebra class?

a great deal___:___:___:___:___:___:___not at all